**NRM351, Forest Ecology - Spring 2021**

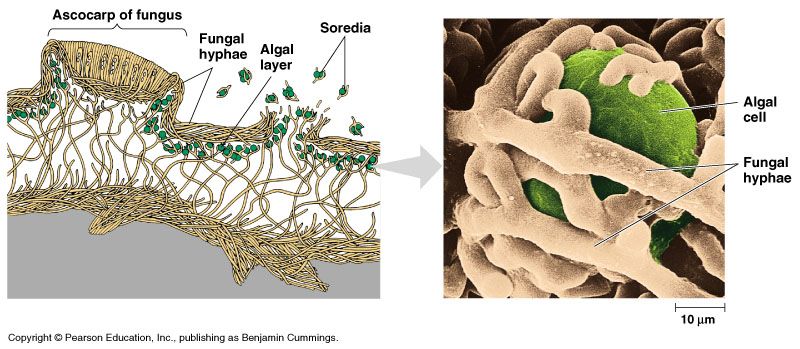
**Research Project: Lichens in YOUR Backyard**

**Pre-lab Reading**

The distribution and abundance of species are affected by the **abiotic** (non-living) and **biotic** (living) environment. Land-use modification and other anthropogenic drivers of environmental change (e.g., air pollution) affect landscape, local, and micro-site conditions. This, in turn, influences the ability of a given species to survive or thrive in an area. Lichens are an excellent group of organisms to explore how abiotic and biotic variables affect the presence and abundance of lichens - right outside your front door!

***What are Lichens?***

Lichens are **composite organisms**, which means that they are made up of two independent organisms living in symbiosis (close physical association). Figure 1 shows the generalized structure of a lichen. Lichens are **mutualistic symbionts**, meaning that both the fungus (the **mycobiont**) and algae or cyanobacteria (the **photobiont**) benefit from the close association. The algae or cyanobacteria are photosynthetic, so the fungus benefits from the carbon compounds (sugars) that the algae or cyanobacteria produce. In turn, the algae or cyanobacteria gain protection, nutrients, and moisture from the fungus. A win-win situation!



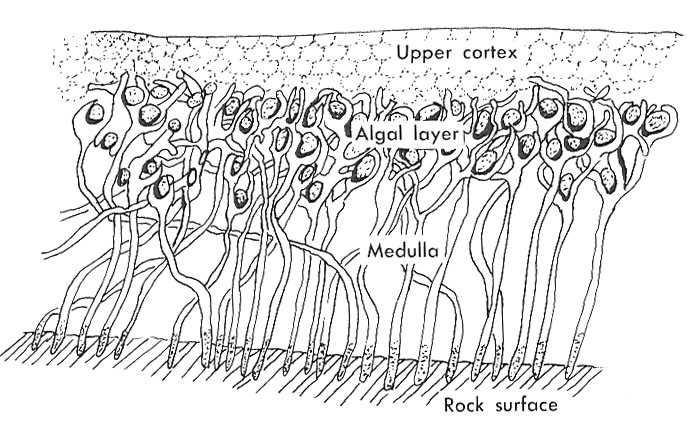


Figure 1. Generalized structure of a lichen thallus (non-reproductive tissues or vegetative parts): upper cortex (outer covering provided by the fungus), algal or cyanobacteria layer (photobiont), and medulla (stores nutrients produced by the photobiont) (<https://archive.bigelow.org/mitzi/spray_3.html>).

***Where are Lichens Found?***

Lichens are widespread and can be found in harsh climates, from hot deserts to cold alpine summits. However, within those ecosystems, they are found in specific **habitats** (natural environments in which they live). The key requirements for lichen habitat are: **water, air, nutrients, light, and substrate type**.

***Water*.** Lichens easily absorb water and water vapor through their **cortex** (outer layer of cells), but lack mechanisms to conserve water during drought periods. Lichens are **poikilohydrous** (water content determined by their surrounding environment); lichens lose water, dry up, and become dormant during dry periods, and rehydrate and become photosynthetically-active when moisture is available.

***Air*.** Not only do lichens absorb water from surrounding air, lichens also absorb nutrients and pollutants. They are sensitive to many air-borne pollutants, and the presence and abundance of some species of lichen are reduced in areas high in atmospheric pollution. For example, sulfur dioxide (SO2) combines with moisture in the atmosphere to form sulfurous acid (H2SO3) or sulfuric acid (H2SO4). High levels of SO2 pollution are associated with decreased lichen respiration and photosynthesis, deactivation of enzymes resulting in reduced metabolic activity and reduced membrane integrity.

***Nutrients*.** Nutrients (e.g., nitrogen, carbon, oxygen) are needed for cellular processes that support lichen growth and survival. Lichens obtain their nutrients from air and water, and, to a lesser extent, their substrate.

***Light*.** Lichens produce their own energy through photosynthesis and, thus, they require light + carbon dioxide + water.

***Substrate*.** Lichens also require a substrate to attach to, and can be found on both natural (e.g., trees, rocks, soil) and artificial substrates (e.g., tombstones, buildings, abandoned equipment). Furthermore, characteristics of the substrate can influence how lichens interact with other aspects of their habitat. For example, substrate pH (e.g., limestone, tree bark with high (basic) pH) can counteract the acidity of SO2 pollution, so that in high pollution areas lichens may be found only on sites with high (basics) pH.

Although lichens are widespread, they need the right amounts of each of these key habitat requirements to survive and thrive!

***Lichens as Bioindicators***

Lichens are ubiquitous in urban and rural areas, and are also an important group of **bioindicators** - an organism whose presence, absence, and/or abundance in an area gives an indication of the degree of health of that ecosystem. For example, some organisms are very sensitive to pollution in the environment, so if pollutants are present, that organism may be absent, or may have different morphology or physiology, or may change its behavior. In contrast, other organisms are less sensitive to pollution in the environment. Documenting which of these bioindicator organisms are present, absent, and/or abundant in an area can be valuable in assessing ecosystem health and understanding whether or not an ecosystem may be impaired by pollution.

Some species of lichens are very sensitive to atmospheric pollution (e.g., nitrogen, sulfur, lead), whereas other species of lichens are tolerant to those pollutants. Lichens can be classified based on the structure of their **thallus** - their nonreproductive tissues or vegetative parts. Luckily, the degree of sensitivity of a lichen to air pollution varies roughly with their growth form. This makes lichens ideal to use as bioindicators.

There are three main types of lichens (Figure 2):

***Crustose*:**

* Crust-like
* Strongly adhere to the substrate; color varies

***Foliose*:**

* Leaf-like
* 2-dimensional (top and bottom “sides”)
* Flat and leafy like lettuce, or with ridges or bumpy

***Fruticose*:**

* Branched-upright or **pendulous** (hanging down loosely)
* 3-dimensional
* Hair-like or upright and shrubby



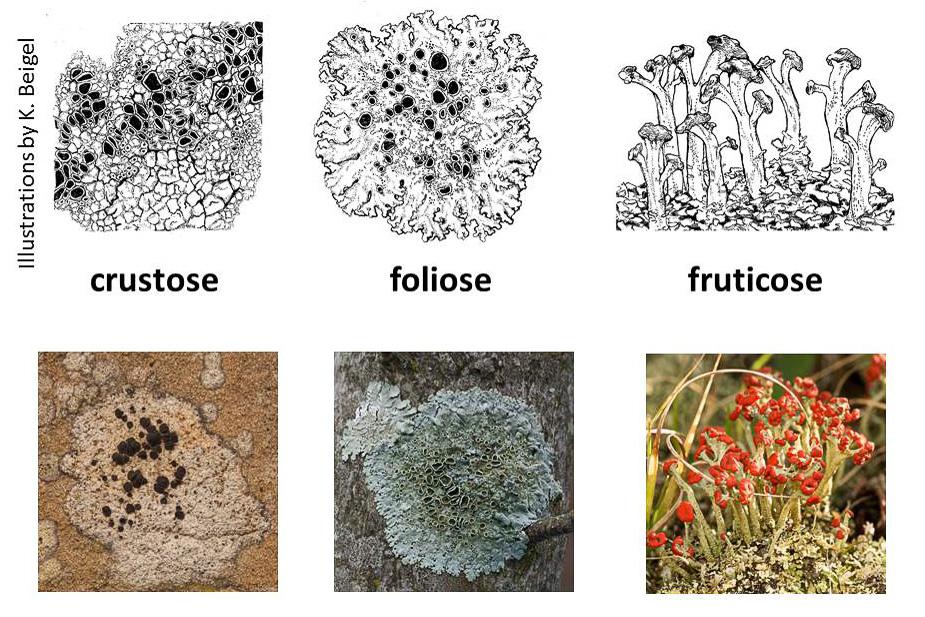


Figure 2. Three main types of lichens: crustose (thin, crust-like, very tightly attached to substrate), foliose (flat and leaf-like; 2-dimensional), and fruticose (upright, like tiny trees or shrubs, or hanging down like a miniature vine) (<https://ohioplants.org/lichen-biology/>).

For this lab, we will be using a modified version of the Hawksworth and Rose (1970) air quality index. This air quality index is based on the type of lichen(s) present, and ranges from 1 to 10, with 1 indicating the poorest air quality and 10 indicating the best air quality (Table 1). In general, lichens that are least sensitive to air quality are crustose, and lichens most sensitive to pollution are fruticose, with foliose lichens in between those two extremities. Two species of fruticose lichen, *Lobaria pulmonaria* and *Teloschistes exilis*, are extremely sensitive to air pollution and, thus, if either species are present, the air quality is considered very high.

Table 1. Lichen air quality index scoring.

|  |  |  |
| --- | --- | --- |
| **Lichen Type** | **Air Quality** | **Air Quality Score** |
| No lichens present | very poor | 1 |
| Crustose only | poor | 3 |
| Foliose present, but no fruticose | moderate to good | 6 |
| Fruticose present | good | 9 |
| *Lobaria pulmonaria* or *Teloschistes exilis* present; fruticose lichens, very sensitive to pollution | very high | 10 |

***iNaturalist Project EREN Lichen!***

Students will be contributing to a new iNaturalist project “EREN Lichen.” iNaturalist is a web-based and smartphone app platform that is used to document observations of species in a particular date and time. It is used and supported by an online community of naturalists, citizen scientists, and biologists, who help in crowdsourcing and confirming species identifications. Submitted observations are accessible to all members of the iNaturalist community, so they provide an excellent resource for exploring, teaching, and citizen science research opportunities. It is a great, user-friendly way to learn more about natural history.

The EREN Lichen project is new, so the number of observations in the iNaturalist project is limited. However, as classes from different locations adopt this module and contribute to the iNaturalist EREN Lichen project, these data can be used to explore hypotheses that address ecological questions across larger scales. The EREN Lichen project data can also be combined with other datasets (e.g., NEON, Living Atlas, NLCD) to broaden these types of analyses, and filling in gaps.

We are looking forward to working with participants in the EREN Lichen project to explore these possibilities as the project grows. So get into the ground-level with this project, and let's see where it takes us!

In this learning module, students will use smartphones and simple equipment to collect field data on lichen presence, abundance, and growth forms on the tree surfaces. Students will join and upload their data into *i*Naturalist smartphone app’s project: EREN lichen. Students will collect measurements of abiotic and biotic variables, such as tree species, tree dbh (diameter at breast height), canopy cover, and bark pH (optional). For each tree sampled, students will document lichen presence and abundance at four locations, corresponding to the four cardinal directions: North, East, South, and West. Students will also have the option to take samples of tree bark to gather data on bark pH (although bark pH is optional because it requires access to deionized water and a pH meter or test strips). Students will develop hypotheses regarding the distribution, abundance, or lichen index of air quality and abiotic or biotic factors of interest. Students will analyze data gathered by their class or, if desired, data gathered from other classes that are contributing to the *i*Naturalist project: EREN lichens.

***Module-specific Learning Goals***

1. Gain experience in species identification, morpho-species classification, and how to make abiotic and biotic measurements in field settings.
2. Develop technical skills using modern technology (smartphone apps, spreadsheet programs, data analysis packages) and everyday materials (ruler, freezer baggie, sharpie permanent marker) to make scientific measurements and analyze data.
3. Examine how bioindicator organisms can be used to assess land-use change, air pollution, and other environmental impacts.
4. Explore how to use multi-site collaborative data can be used to conduct regional and continental scale analyses to address ecological and macroecological questions.

Co-Authors: Dr. Danielle Garneau (SUNY-Plattsburgh), Dr. Matthew Heard (Belmont University), Dr. Mary Beth Kolozsvary (Siena College); Project e-mail: [eren.lichen@gmail.com](mailto:eren.lichen@gmail.com)

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